OHIO RIVER BASIN PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

Tenth Progress Report
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Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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1. Introduction.

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for the Ohio River Basin. Current precipitation frequency estimates for the Ohio River Valley are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *NWS HYDRO-35* "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al 1977) and *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964). The new study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual and seasonal precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all appropriate rainfall data for the Ohio River Basin study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14. They will also be made available on the Internet with the additional ability to download digital files.

The study will produce estimates for 13 states. Parts of nine additional bordering states are included to ensure continuity across state borders. The Susquehanna River and Delaware River Basins are included in the study area. The core and border areas, as well as regions used in the analysis, are shown in Figure 1.

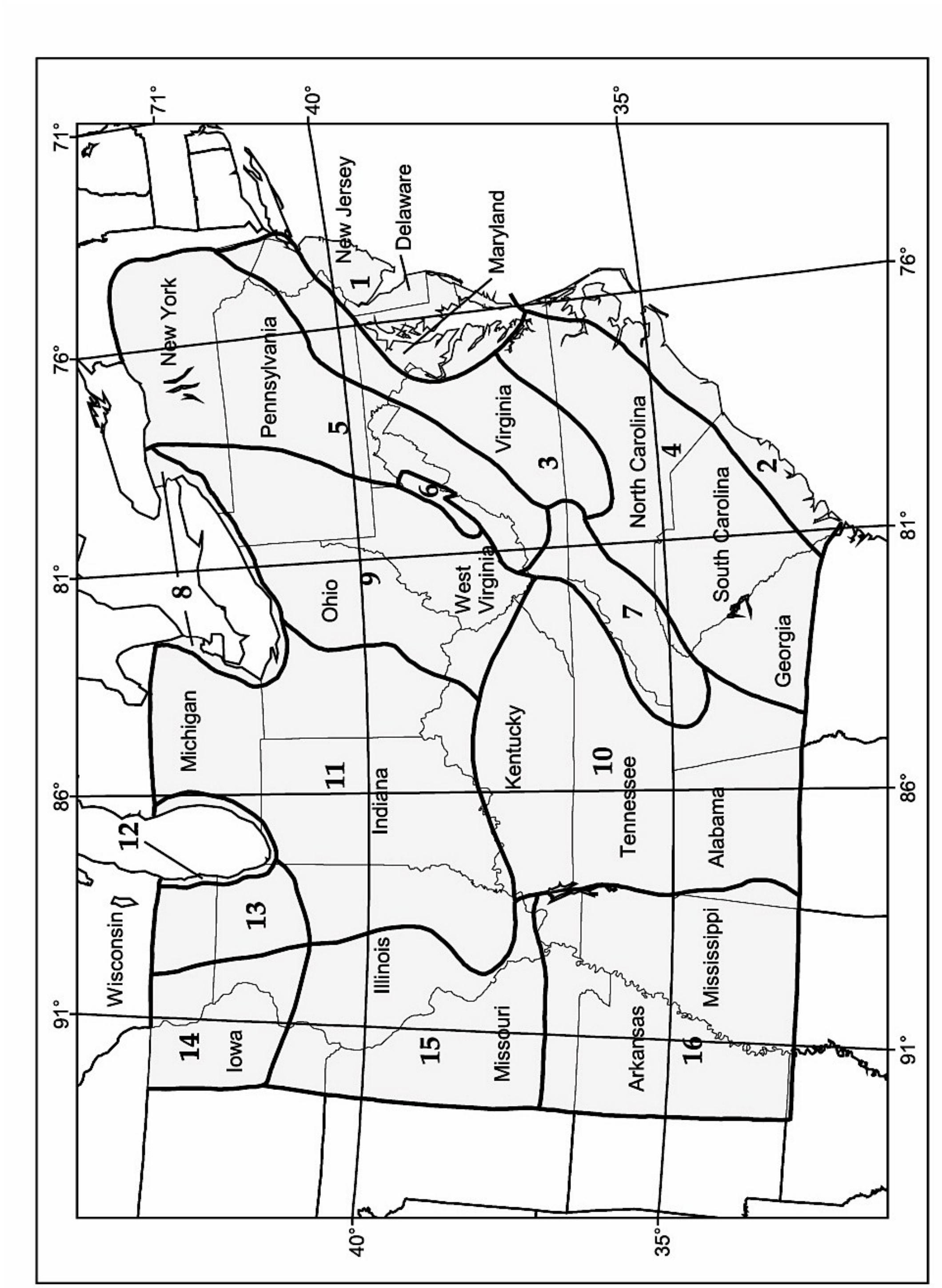

Figure 1. Ohio River Basin Precipitation Frequency study area and region boundaries.

2. Highlights.

The digitized pre-1949 TD3206 daily dataset from NCDC has been added and quality controlled. Additional information is provided in Section 4.1, Data Collection and Quality Control.

Software to extract annual maxima of longer duration events (4-day through 60-day) has been developed and tested. Additional software has been developed to screen 1-day annual maximum series for large gaps in time using specific “Gap Check” criteria. Stations will be merged and adjustments made where appropriate to produce more congruent data records. Additional information is provided in Section 4.2, Software Updates.

Contract formalities between HDSC and the Spatial Climate Analysis Service (SCAS) at Oregon State University (OSU) have been finalized. As soon as HDSC has finalized the calculations of the point values, efforts will be immediately underway to spatially interpolate the values with PRISM. Additional information is provided in Section 3.1.2, Spatial Interpolation.

Development is underway to add functionality to the Precipitation Frequency Data Server (PFDS) to extract station-specific data. This functionality will allow for a review of the point-precipitation frequency estimates before the interpolated grids are finalized. Additional information is provided in Section 3.1.3, Precipitation Frequency Data Server.

HDSC has decided to prepare and publish depth area duration (DAD) values in a separate report. Additional information is provided in Section 3.1.4, Spatial Relations (Depth Area Duration Study).

3. Status.

3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percent completed per task. Past status reports should also be referenced for additional information.

Ohio River Basin study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [99%]:
- Daily
- Hourly
- 15-minute
- N-minute

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [0%]:
- Daily
- Hourly
- 15-minute
- N-minute

Spatial Interpolation [0%]
- Create grids of interpolated means for each duration using PRISM (see Table 1)
- Subject grids of interpolated means to external review
- Create smoothed regional growth factor (RGF) grids using GRASS: (5-1000) yr (1-12) hr, (5-1000) yr 24hr, (5-1000) yr (2-60) day
- Establish regions from spatial, topographic and meteorological variables
- Run L-moments for regional growth factors to generate dataset

Table 1. Proposed List of Grids of Distributed Means.

Duration	Season
1-hr	all
1-hr	cool, warm
2-hr	all
3-hr	all
6-hr	all
6-hr	cool, warm
12-hr	all
24-hr	all
24-hr	cool, warm
48-hr	all
4-day	all
7-day	all
10-day	all
20-day	all
30-day	all
45-day	all
60-day	all
Total: 26 (14 all, 6 warm, 6 cool)	

Precipitation Frequency Maps [0%]

- Multiply appropriate RGF and distributed mean grids to produce precipitation frequency grids for durations and seasons shown in Tables
- Apply domain-wide conversion factor to the 1-hour precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids
- Perform internal consistency checks (comparing rasters of sequential duration and frequency)

Table 2. Proposed List of Precipitation Frequency Rasters.

Duration	**Frequency**	**Season**
5-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
5-min	2-yr, 100-yr	cool, warm
10-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
10-min	2-yr, 100-yr	cool, warm
15-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
15-min	2-yr, 100-yr	cool, warm
30-min	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
30-min	2-yr, 100-yr	cool, warm
1-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
1-hr	2-yr, 100-yr	cool, warm
2-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
3-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
6-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
6-hr	2-yr, 100-yr	cool, warm
12-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
24-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
24-hr	2-yr, 100-yr	cool, warm
48-hr	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
4-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
7-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
10-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
20-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
30-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
45-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all
60-day	2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr	all

Data Trend Analysis [0%]
- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Seasonal Analysis [50%]
- Create graphs of percentage of precipitation maxima in each month of a year

Temporal Distributions of Extreme Rainfall [0%]
- assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- prepare graphs of representative storm-types and seasons

Deliverables [20%]
- Prepare data for web delivery
- Prepare documentation for web delivery
- Write hard copy of Final Report
- Publish hard copy of Final Report

Additional Work:

Spatial Relations (Depth Area Duration Study) [20%]
- Obtain data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations from each network
- Compute ratio of maximum to average depth for all durations and networks and plot
- Draw curves of best fit (depth area curves) for each duration and network

3.1.1 Data Collection and Quality Control.

NCDC had provided HDSC with pre-1949 daily data. This data has been added to the dataset and quality controlled.

The Huntington, Louisville and Nashville U.S. Army Corps of Engineers (COE) districts have provided us with data extending through December 2000. The appended data will be quality controlled in the coming weeks.

3.1.2 Spatial Interpolation.

Contract formalities between HDSC and the Spatial Climate Analysis Service (SCAS) at Oregon State University (OSU) have been finalized. As soon as the point precipitation frequency estimates and mean annual maxima values are calculated by HDSC, SCAS will use PRISM (Parameter-elevation Regressions on Independent Slopes Model) to spatially interpolate the mean annual maxima values (a.k.a. “index flood”) to grids. At HDSC, the “index flood” grids will be multiplied by the appropriate regional growth factor (RGF) grid to derive each of the precipitation frequency grids. We are evaluating different spatial smoothing techniques to mitigate any large RGF boundary differences.

3.1.3 Precipitation Frequency Data Server.

Development is underway to add functionality to the Precipitation Frequency Data Server (PFDS) to extract station-specific data. Until now, users could only select a longitude/latitude location or an area, but soon the PFDS will have a pull-down menu to select a specific climate station. The menu of climate stations will represent the same stations used in the study, including the option of choosing which type of gage data (N-minute, hourly, or daily) to extract. Likewise, the data will be the exact data as output by the L-moment software used in the study. This functionality will allow for a review of the point-precipitation frequency estimates before the interpolated grids are finalized. When final estimates have been established at each station, a clickable station map will be established.

3.1.4 Spatial Relations (Depth Area Duration Study).

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in a report separate from NOAA Atlas 14.

4. Progress in this Reporting Period.

4.1 Data Collection and Quality Control.

The NCDC TD3206 daily dataset, which primarily consists of data before 1949, has been formatted, added to the existing dataset, and quality controlled. The dataset will be included in the precipitation frequency calculations. The quality control process involved methods such as comparing values with other data sources (e.g., NCDC Climatological Data) and with hourly and daily values at other local stations. The addition of this dataset increased the number of stations in the Study by 5%; the number of data years was increased by an average of 5% (Figures 2 and 3). The average period of record also increased by an average of 5 years or 9%. Table 3 displays the current number of daily stations per region that will be used in the L-moment analysis.

Figure 2. Number of stations (with ≥20 years of data) per region before and after TD3206 update.

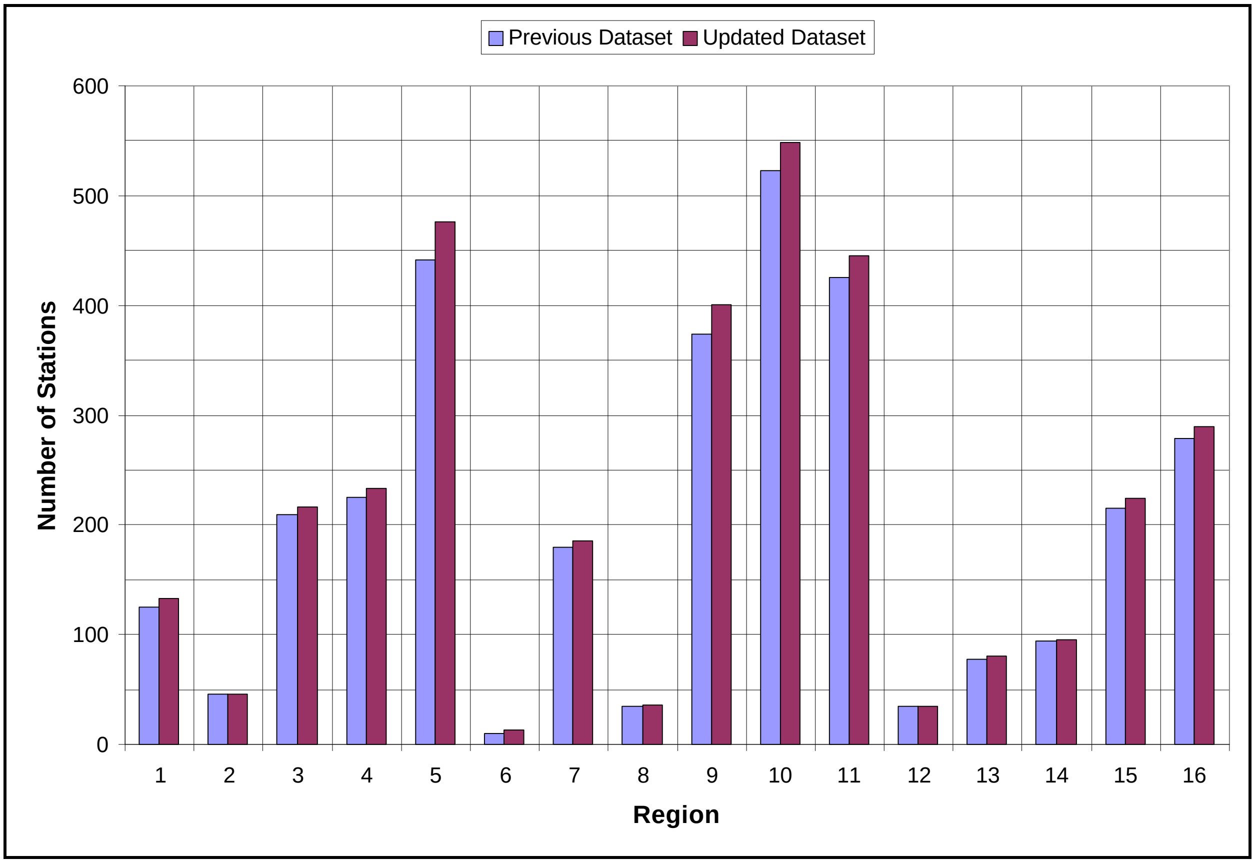

Figure 3. Average data years per station (with $\geq$20 years of data) by region before and after TD3206 update.

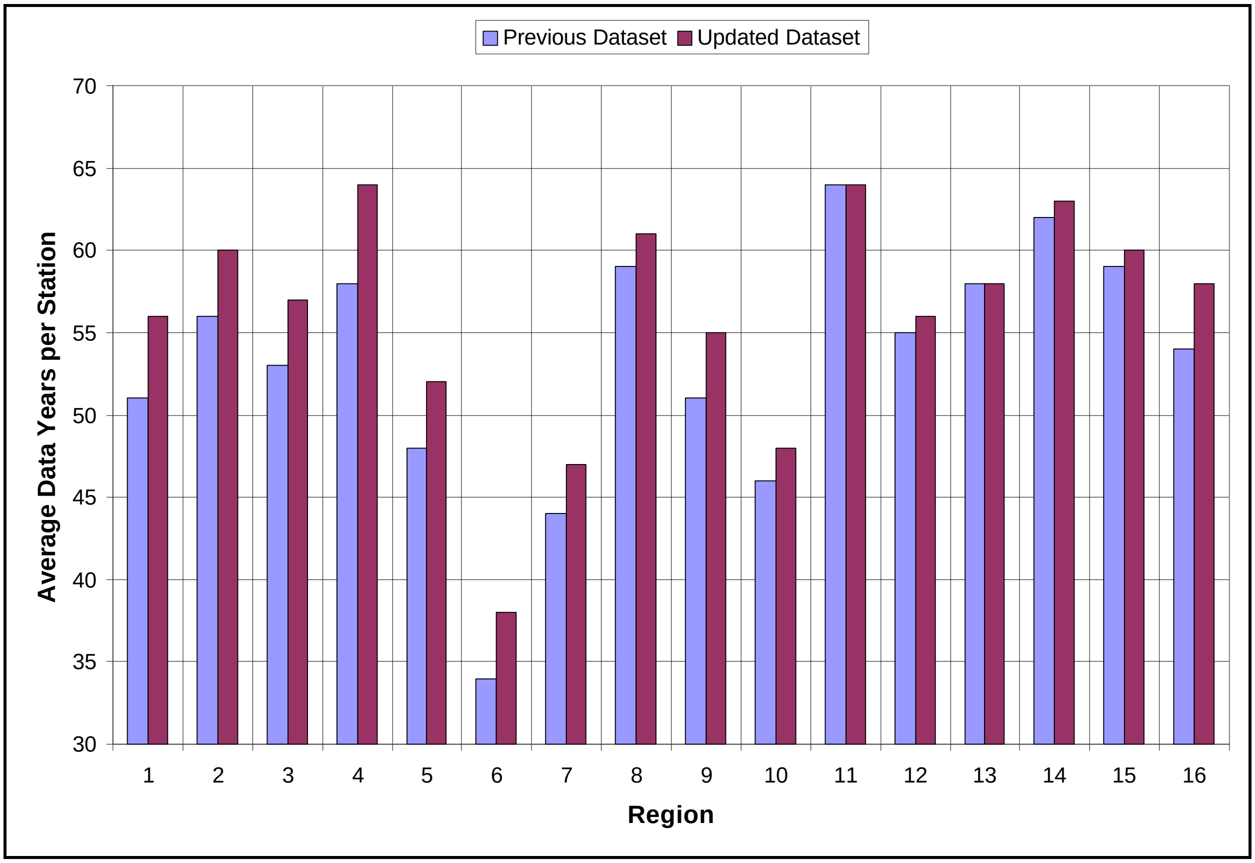

Table 3. Number of daily stations per region to be used in L-moment analysis.

Region	Daily stations ≥20 data years
1	133
2	46
3	216
4	233
5	476
6	13
7	185
8	36
9	401
10	548
11	445
12	35
13	80
14	95
15	224
16	290
Total	**3456**

4.2 Software Updates.

Some stations included in the Study may have multiple missing years. Large gaps (i.e., sequential missing years) in an annual maxima series cause concern about the data series consistency. It is not possible to guarantee that two given data segments are from the same population (same climatology, same rain gauge, same exact physical environment) from one side of the gap to the other.

Software has been developed to screen all data records for large gaps using specific "Gap Check" criteria before the data will be used in the L-moment analysis. Station records with large gaps will be flagged by software and examined case by case using a conservative approach. Nearby stations will be inspected for concurrent data years to fill in the gap if they pass the statistical test for consistency. Latitude, longitude and elevation will be considered when examining nearby stations. Also, if there are sufficient years in each data segment, a t-test will be conducted on the two segments to assess the statistical integrity of the data record. To produce more congruent data records for analysis, station record length may be adjusted.

Software to extract annual maxima of longer duration events based on the annual maximum criteria has been developed and tested. Therefore, we now have the tools to extract the annual maximum series for 1-day through 60-day precipitation accumulations once the datasets are finalized.

4.3 Spatial Relations (Depth Area Duration Study).

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in a report separate from NOAA Atlas 14. This quarter the focus has been on gathering and formatting data from geographically spaced dense area rain gage networks (DRNs) across the United States. These DRNs will be used in conjunction with NCDC hourly stations to develop DAD relationships. Thirteen networks have been identified thus far and are summarized in the table below.

Table 4. Dense Area Rain Gage Networks.

DRN	Period of Record (Concurrent)	Number of Stations
Coshocton, OH	1940 - 1990	10
Riesel, TX	1968 - 2001	21
Walnut Gulch, AZ	1955 - 1990	18
Reynolds Creek, ID	1965 - 1996	52
Tifton, GA	1968 - 1980	45
Alamogordo Creek, NM	1955-1977	66
Hastings, NE	1939-1962	10
Safford, AZ	1939-1971	11
Hawaii (NCDC data)	1965-2000	32
Danville, VT	1960-1974	13
Blacksburg, VA	1957-1972	15
Goodwin, MI	1981-2001	67
Lafayette, IN	1940-1953	8

5. Issues.

5.1 Updating Precipitation Frequency Atlases for the Entire Nation.

HDSC is currently updating the precipitation frequency atlases for a number of areas across the country and has been asked to expand the work to the entire country. Studies are underway for the Ohio River Basin and surrounding states, the Semiarid Southwest, Hawaii, and Puerto Rico and the Virgin Islands. Quarterly progress reports, which include schedules, for these studies are available at http://www.nws.noaa.gov/oh/hdsc.

Precipitation frequency studies are performed using funds provided by other federal, state and local agencies. HDSC is participating in an effort to assemble funds to update the precipitation frequency atlases for the entire United States. Hopefully sufficient funds can be identified to begin work during the summer of 2002. The full national update will use a consistent technical approach to data preparation, frequency analysis and mapping as well as a consistent and more user-oriented approach to publication.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section.

Data Collection and Quality Control [March 2002]
L-Moment Analysis/Frequency Distribution [May 2002]
Spatial Interpolation [October 2002]
Precipitation Frequency Maps [November 2002]
Temporal Distributions of Extreme Rainfall [July 2002]
Implement Precipitation Frequency Data Server (PFDS) [January 2003]
Write hard copy of Final Report [January 2003]
Implement review by peers [June 2002]
Publish hard copy of Final Report [March 2003]

Spatial Relations (Depth Area Duration Studies) [January 2003]

6.1 Data Collection and Quality Control.

The Huntington, Louisville and Nashville U.S. Army Corps of Engineers (COE) districts have provided us with data extending through December 2000. The COE datasets have been appended to co-located NCDC stations with datasets ending in December 1998. The appended data will be quality controlled by the first week of April.

6.2 L-Moment Analysis/Frequency Distribution.

A comprehensive L-moment statistical analysis will be done on all datasets through December 2000 for all durations and all regions. The tasks involved with the statistical analysis will take roughly two months for all 16 regions in the Ohio River Basin study area.

6.3 Trend and Shift Analysis.

The dataset will be analyzed for any trends or shifts in annual maxima through time. T-tests will deduce any linear trends in annual maxima or in variance, while t-tests, Mann-Whitney tests and Chi-squared tests will determine any shifts in means of annual maxima. The end products of these tasks are analyses and graphs that will be included in the final document.

After completion of the trend and shift analysis, data quality control will be performed on stations exhibiting a significantly high linear trend and/or shift in the annual maxima time series data.

6.4 Temporal Distributions of Extreme Rainfall.

Our methodology for developing temporal distributions of extreme rainfall events will be further researched and verified. Our method is based on an Illinois State Water Survey Report (Huff, 1990) and determines the maximum and median precipitation event time distributions for 12, 24 and 72 hour duration events. Time distributions of hourly maximum and median events will be sorted, averaged and plotted by storm area, quartile, duration and season.

6.5 Precipitation Frequency Data Server.

Two PFDS changes planned for the next quarter are extending the return period to 1000 years and changing the precipitation frequency estimate graph from a bar to a line graph.

6.6 Spatial Interpolation.

Due to contracting and data preparation delays, the period of performance for the PRISM gridding contract has been adjusted to April 1, 2002 through December 31, 2002. A kickoff conference call will initiate the task in April; the implementation of project schedules and tasks will be discussed. A status meeting is tentatively scheduled in Silver Spring in July or August to discuss the interpolation methodology and draft maps.

6.7 Spatial Relations (Depth Area Duration Study).

Research will continue into selecting the method to be used for computing the DAD curves. Software to decode and format the data files and the DAD computations will continue to be developed. As DRNs are located, they will be added to our database.

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